OHE
373.19713
Ont2e / C-S

SPACE AND MAN

Ontario Department
of Education

1969

Senior Division

CONTENTS

ABSTRACT ii

SALIENT FEATURES 1

SYLLABUS 3

- The Moon 3
- Introduction to Flight 4
- The Current Space Scene 4
- Using Telescopes 5
- Life for Man in Space 5
- The Stellar Population 6
- Space Law and Politics 6
- The Way Into Space 7
- Great Ideas in Astronomy 8
- Fiction About Space 8
- Opening the Windows 9
- Rocketry 9
- Probing the Upper Atmosphere 10
- Further Themes for Student Choice 11
- The Impact of Space on Humanity 11
- Canada's Contribution in Space 12
- Applications of Mathematics 12
- Origins 13
- Communication by Satellite 13
- The Planets 14
- Science and Technology 14
- Are We Alone 15

IMPLEMENTING THE LOCAL PLAN 16

- Determining the Program 16
- Sharing the Teaching 16
- Three Ways for One Theme 16
- Assessment 20
- Student Projects 20

RESOURCES 22

- Periodicals 22
- Books 23
- Other Learning Materials 27

Cover photo: *National Research Council*

ABSTRACT

These guidelines to *Space and Man* are provided so that teachers and students will be able to plan for studies centered on space. The domain of the course extends from the earth's surface through space to the farthest galaxies. In time, the domain stretches from the earliest astronomical observations to the present use of sophisticated probes and instruments.

Just as important as the characteristics and exploration of space is the experience of mankind with space. Accordingly, the domain includes many aspects of man's concern with space. For centuries men have looked up from the world at their feet, have pondered over origins, have speculated, and have recorded their thoughts in words and other art forms. Now that man has entered space, new problems of law, social responsibility, politics, personal values, technical excellence, and scientific significance have emerged. The domain of this course, therefore, is as broad as man's experience in space.

Space and Man extends through the humanities and the sciences. Itself an interdisciplinary course, it uses the disciplines of mathematics, language, the sciences, economics, history, political science, engineering, and many others as tools. The specialized skills and data from the disciplines support the course in a natural fashion. Thus the student will derive general education, rather than training in any one discipline.

The syllabus lists at random some twenty themes that represent possible topics for the course. Through consensus, staff members and students can select the range of topics which will best define a course. No special order of topics is suggested, nor is any particular continuity proposed here, but rather it is proposed that each class adopt the order as well as the themes suitable for the goals, interests, and talents of its members. The thread of continuity that students follow will be one that they themselves devise.

Some of these topics may prove suitable for intensive treatment, some for extensive treatment. Some will be suitable for group work, some for individual pursuit. Throughout the program there is frequent occasion to use films, books, periodicals, apparatus, instruments, and other prime materials of the men who work with space.

In some degree the selected themes overlap. Students who begin their studies from discrete themes will find that events in space are related to each other. So extensive are the relations between ideas, that it is not likely that significant, relevant ones will be missed. What might be omitted in one theme may well emerge in another.

In brief, *Space and Man* may provide another domain in which to develop understanding. No attempt has been made to provide a course as stable as a pyramid where one concept logically follows another. Rather, these guidelines make it possible for each student to develop a network of understanding, like strands of spider silk stretching to every corner and interlacing at a thousand points.

Digitized by the Internet Archive
in 2019 with funding from
University of Toronto

https://archive.org/details/spacemanseniordi00onta

SALIENT FEATURES

Space and Man recognizes man's experience in space, and provides for study in this new domain.

Until this century, man has lived close to the interface between the atmosphere and the surface of land and water. Trips upwards by balloonists and downwards by divers and miners were short when compared to the size of the earth. Most school studies, such as geography, chemistry and history, however, had their locale in this interface. This course includes a new dimension, the dimension leading to the depths of space.

From these depths, students can select areas for inquiry and exploration. Space with its diversity presents a field of study almost infinite in scope. It starts from the air upwards through cloud and sky, to the upper atmosphere, to the moon, and from the sun to the farthest planets and beyond. The events within this domain are numerous: the changing cloud cover, the aurora, the rivalries in space exploration, meteor trails, the economics of space programs, the motions of the planets, the decisions that enhance international co-operation, the design of space vehicles, safety and air travel, aerodynamics, and cosmology.

Each layer of the space above the earth has its own story of penetration, from kites and balloons to aeroplanes and rockets. The operation of telescopes, rocket probes, and sensitive satellites shows the measure of our science and technology.

In addition to suggesting a new field for study, this course offers a new opportunity for decision-making. Students and teachers can design their own programs from the twenty themes proposed.

Some courses in the past have been largely oriented to the presentation of facts, concepts, and principles in one suggested order to achieve one pre-determined end. In this course, it is assumed that each class has its own purposes, each student his own objectives, and each teacher his own hopes. Then, to move toward these goals, the class will have the responsibility of discussing and selecting themes.

This dialogue can be a continuing feature, for as themes develop, new interests appear. Perhaps dialogue and the achievement of consensus are as important as the other experiences of the program. For to make dialogue does not just mean to discuss, but it also means to learn, to understand, to respect, to advise, to participate, to build, and to become responsible.

Who are likely to choose *Space and Man* as part of their program?

Many students are seeking a general education that will probe for answers to the great questions, "What is this world like? What is my place in this world? Who am I? " This course can open up some of these important questions. Some students whose interests lie in the humanities may want to feel at home in the other culture, the culture of science and technology. This course can bridge the two.

Other students whose main interests lie in the sciences and technology may choose *Space and Man* because some themes lead from these fields into the other world of arts and letters. The course is not, however, designed to prepare students for post-secondary education in the science-oriented fields. Those intending to continue their education in science and technology are more likely to elect courses in such school subjects as biology, chemistry, mathematics, and physics.

Space and Man follows themes, not disciplines. Quite clearly the course is not physics, although some work may include physics; nor is this a science course although many students may select themes that will be successfully followed only if the student at work refers to one of the disciplines of science. For *Space and Man* crosses through many disciplines, while it uses their resources. An interdisciplinary study such as this, becomes strong when the armoury of the subject disciplines is put within reach of student hands. The course becomes less effective if no reference is made to the heritage of experience represented in the specific disciplines and if every situation is treated as a wholly new event.

Though the course is centred around space, it invites departures into any matter that interests the student. From themes it may lead to the disciplines. That it leads to planets, stars, and galaxies is natural, and of course here the student will refer to the discipline of

astronomy. That some students will read fanciful stories of space travel is probable – they may even write their own – and of course this is a departure towards literature and journalism. Similarly when the students read of the costs of space projects they will consider economic issues. When they hear of rival national claims, they will find decisions that are rooted in the specialties of history and law. But the course never becomes centred on disciplines.

Students of *Space and Man* will likely see themselves as citizens with a responsibility both for their fellow Canadians and for the welfare of mankind. Recent achievements in space have not ended the world's problems, nor are decisions in this domain easy. Science and technology are themselves amoral, yet man's use of them involves social, economic, and political decisions. Each student and citizen understands to a greater or lesser degree the importance of these decisions, yet all are affected by them. Those who do not understand the basis for the decisions become mere consumers of technology, and perhaps feel themselves aliens in a changing world.

Those taking this course may be able to appreciate that one of the problems involved in research in space and astronomy is justifying the expenditure of public funds on specific projects. There are usually cogent arguments, both pro and con. Students can have the intellectual and emotional satisfaction of taking a stand on the relevance of the objective and on the suitability of the means to achieve that objective. Should public funds be allocated to the building of large optical telescopes and communications satellites? Or should such funds be allocated to pollution control, the reduction of poverty, and the encouragement of the arts?

The issues are complex, and it may be difficult for a student to determine his position in the wide spectrum of opinion. What is important is that discovery and understanding of some aspect of the scientific culture become a part of his experience. Then he can have a basis on which to develop the ability to evaluate critically the scientific and technological factors that influence his daily life.

This course, with its many optional themes, presents a clear opportunity for a new, more open education. Given this freedom, students can accept both the responsibility for designing the program and for undertaking the tasks that emerge. Teachers and students can select themes in consensus.

The development of the course can follow any path that seems natural and reasonable. It matters little that some classes and some students initially concentrate on nearby space or on sun-earth relations, while others begin with the mechanisms of space probes or the examination of lunar photographs. Students will shift quite naturally to other items, as they see diminishing returns from some topics in certain themes. Week by week the class can extend its network of understanding.

Teachers who know the many diverse networks that are possible can support the inquiries, and yet not remove the frequent occasions when young people can be left to rely on themselves. To grow through experience, to trust themselves, and to become adventurous, can be just as significant achievements for young people as discovering man's new place in space.

SYLLABUS

The syllabus lists some twenty topics to guide students and teachers as they develop a program. Clearly no two classes will follow the same program. Even within one class, individual students may frequently move in divergent paths as they follow strong personal interests. The main unifying factor rests in the distinct domain of the course: the things and the events in space, from the distant galaxies right to the earth itself. The syllabus provides suggestions for the study of this domain.

It is assumed that no group can define the program better than the staff and the students who will be working together on the course. Accordingly *there is no suggested selection of themes.* What turns out to be the essential core for one class may well be considered a peripheral interest for another group of students.

Similarly no set number of themes is proposed. Many classes may find that two or three themes prove adequate for a semester. Seven or eight may be a suitable year's work. Another six or seven might form the basis for a second year of space studies.

The syllabus is designed to be flexible. *No special order of themes is suggested.* The themes are deliberately presented in random order, so that in each school the thread of continuity that seems suitable may be chosen. Further, the format of the items in the syllabus varies greatly. Some themes are proposed in considerable detail; some are portrayed with a broad brush. Some themes, such as *Space Law and Politics* may readily be transformed into two themes. Some possible themes have been omitted. The seventeenth one, *Further Themes of Student Choice*, invites innovation. The whole syllabus, and each of the items, can be considered starting-points from which a network of experience and understanding can grow.

The Moon

With current space programs there has been a rejuvenation of the study of the moon. With a small telescope, features of the lunar surface can be observed, and in some instances, compared to the geological and geographic features of the earth. Photographs of the moon are numerous, and easily obtained from the McLaughlin Planetarium and commercial suppliers at a reasonable cost. Students can use the photographs that astronomers use.

The motion of the moon, its appearance by day and night, and the frequent occultations and eclipses make it suitable for continued observing.

Alter, D. *Pictorial Guide to the Moon.* New York, Crowell, 1967

Baldwin, R.B. *The Measure of the Moon.* Chicago, University of Chicago Press, 1963

Baldwin, R.B. *The Moon: A Fundamental Survey.* New York, McGraw-Hill, 1966

King, H.C. *The World of the Moon.* London, Barrie and Rockliffe, 1966. 125 p.

Kopal, Zdenêk. *The Moon.* London, Chapman and Hall, 1963. 152 p.

Rousseau, Pierre. *La lune, terre d'avenir.* Paris, Libraire Hachette.

Ryan, Peter. *The Invasion of the Moon 1969.* Harmondsworth, Penguin, 1969. 189 p.

Introduction to Flight

While the domain of the whole course extends from the atmosphere at ground level to the far regions of the celestial sphere, some classes may choose this theme concerning flight, which is chiefly concerned with the lower atmosphere. Three presentations on aviation have been prepared: one is science-oriented, one history-oriented and one people-oriented. These will be found in a later section of this booklet on pages 17-19.

Students and teacher can choose a treatment linked to the science of aerodynamics, to the unrolling of events, or to the personal achievements in human endeavor. If desired, students taking this main theme might still be studying it in groups from three entirely different points of view.

This theme lends itself to in-school and out-of school education. Men and women who work every day in the flight industry can bring their expertise to school. At other times the students could make field studies in some of the following locations:

Airport	Flying School
Control Tower	Research establishment
Control Centre	Museum
Aircraft maintenance facility	Aircraft design and construction facility

Bishop, W.A. *Winged Warfare.* New York, Ace Books, 1967
In World War I, Billy Bishop was the top ace of the Allies.

Chichester, Francis. *Alone Over the Tasman Sea.* London, Temple Press, 1966
The classic saga of dead reckoning air navigation.

Cosgrove, Edmund. *Canada's Fighting Pilots.* Toronto, Clarke, Irwin, 1966

Ellis, Frank H. *Canada's Flying Heritage.* Toronto, University of Toronto Press, 1961
A history of aviation in Canada.

Gatland, K.W. *Spacecraft and Boosters:* Volumes 1 & 2, London, Iliff Books, 1964-65
These volumes provide a detailed historical summary.

Kermode, A.C. *Flight Without Formulae.* London, Pitman, 1967. 291 p.
A simple introduction to the theory of flight.

Rolt L.C.T. *The Aeronauts.* London, Longmans-Green, 1966. 267 p.
A complete coverage of the history of ballooning.

Shaw, Margaret M. *Bush Pilots.* Toronto, Clark, Irwin, 1962
About the fliers who opened up Canada's North.

Wagenvoord, James. *Flying Kites.* New York, Macmillan, 1968. 127 p.
Instructions for building and flying twelve kites conclude this treatise that describes the history of kite-flying.

The Current Space Scene

When the news media announce an event in space, there may emerge a fresh theme at a "teachable moment". Then the decision to alter advance plans may be made, and the current event becomes the program. Good examples of such events are an eclipse of the moon, sightings of a comet, and launching of an upper atmosphere probe. Here is a brief report from one teacher in a pilot class for this course.

> "When a recent Apollo space craft was launched, three classes watched the launching live on tv. The program was taped to show to two other classes who could not be accommodated at the time, and portions of the taped television program were re-shown later for review. Since the splashdown took place early in the morning this also was taped and shown to the class later the same day. During the ten days between lift-off and splashdown, the whole Apollo project was studied in depth. Class enthusiasm during this time was high. I think this was because they felt they knew what was going on, could follow the newspaper reports and broadcasts, could explain to parents, brothers and sisters, and generally had a rare feeling of being fairly expert in a particular field."

Using Telescopes

Instruments can become starting-points. Programs for telescope observations can be organized from month to month, with perhaps half an hour's observation time reserved for three or four students. Here is a sample of a first program used in October.

"Finding constellations visually using the bright star method and star finder (Small Dipper, Large Dipper, Lyra, Cygnus and the stars Altair, Arcturus and Capella).

Finding the galaxy in Andromeda visually and by co-ordinates. Observing M31, and M32 with different magnifications.

Comparing the effect of change of magnification when viewing a star and a planet."

The program of observations might lead some students to building a telescope, others to making a survey of historically important instruments and others to photographing astronomical objects.

Beet, E.A. *Teaching Astronomy in Schools.* Cambridge, Cambridge University Press, 1962. 73 p.
A reference guide for teachers who plan to undertake work in astronomy.

Menzel, D.H. *Field Guide to the Stars and Planets.* Boston, Houghton, Mifflin, 1964. 397 p.
A pocket guide to the night sky.

Moore, Patrick. Yearbook of Astronomy, 1968. London, Eyre & Spottiswoode, 1967. 232 p.
This yearbook designed for amateurs contains data for the year and other articles on a wide range of subject.

Northcott, R.J. (Editor). *Observer's Handbook.* Royal Astronomical Society of Canada, 252 College Street, Toronto 130, Annual.

Olcott, William et al. *Field Book of the Skies.* (4th Edition). New York, Putnam, 1954

Rudaux, Lucien et G. de Vaucouleurs. *Manuel pratique d'astronomie.* Paris, Librairie Larousse, 1952

SRAC. *Annuaire astronomique de l'amateur.* Published annually by the Montreal Centre of the Royal Astronomical Society of Canada, Box 904, Station 5, Montreal 110, Quebec.

Texereau, Jean. *La construction du télescope d'amateur.* Paris, Société Astronomique de France, 1951

Texereau, Jean. *How to Make a Telescope.* New York, Anchor-Doubleday, 1963

Texereau, Jean. *Notes pratiques pour les observateurs débutants.* Paris, Société Astronomique de France, 1963

Life for Man in Space

Several fundamental biological problems face man's exploration of space. The first is the problem of supporting human life away from the earth's environment. The second is the question of the kinds of life-forms that may be encountered in the course of space exploration.

What biological problems may students identify as presenting difficulties to space travel? They may meet the problem of the restricted amount of food and air that can be carried on spacecraft, and the problems of disposal of excreta. They may look for the protection necessary against exposure to prolonged weightlessness, isolation, unusual atmospheric conditions, radiation hazards, and the limitations on muscular exercise. Some may investigate the cyclical re-use of elements in space vehicles. Others may identify more sophisticated problems such as the contamination of new extra-terrestrial environments with terrestrial organisms, and the converse.

Related laboratory work is possible. With aquaria and vivaria, the closed systems of space craft can be simulated. Gravity effects on plant roots can be studied with a simple clinostat built from a record player. Micro-organisms may be cultivated and thus the problems of contamination will emerge.

How can students be guided in their search for answers? When students are referred to source materials, they will get only partial answers to problems. Such answers would not be entirely satisfactory and perhaps the dissatisfaction would lead to improved understanding of the complex nature of the problem. The new insight should result in a re-definition of the problem.

Working on this theme, students may discover that not every problem has a current solution. When a student realizes that his mind has come to the frontier of knowledge, he

learns that science does not know everything. An event of considerable significance in his education will then have taken place.

Caidin, M. & G. *Aviation and Space Medicine.* New York, Dutton, 1962. 215 p.
An account of the doctors, scientists and engineers working to conquer the vertical frontier.

Henry, James P. *Biomedical Aspects of Space Flight.* New York, Holt, Rinehart and Winston, 1966. 174 p.
This paperback describes how physiological problems of man going into space are solved.

The Stellar Population

Probably the sun will be the starting point, for it seems to be about an average star. It is also a good subject for radio study. Part of an appreciation of the stellar population can come through observation of the stars distributed in the night sky.

Some students may be interested in the rejuvenation of astronomy at the beginning of the century with the emergence of astrophysics.

Brandt, John C. *The Sun and Stars.* New York, McGraw-Hill, 1966

Meadows, A.J. *Stellar Evolution.* Oxford, Pergamon, 1967. 176 p.
Modern theories of the birth and death of stars are described for the general reader.

Menzel, D.H. *Our Sun.* Cambridge, Harvard University Press, 1959

Page T. and L.W. Page. *Starlight.* New York, Macmillan, 1968

Page T. and L.W. Page. *The Evolution of Stars.* New York, Collier-Macmillan, 1968

Space Law and Politics

A survey of existing and potential uses of space technology

This would involve a description of various uses in telecommunications, meteorology, navigation, geodesy, cartography, resource surveys, and military affairs.

The need for space law and its making

The increasing number of both users and uses requires legal regulation to preclude, or at least minimize interference and at the same time protect the interests of all present and future users.

Study could be made of the mechanics of space law-making and the role of the states, the role of the United Nations and its specialized agencies such as UNESCO, the World Meteorological Organization, and the International Telecommunications Union.

The Outer Space Treaty of 1967

Students might analyse the major provisions of this space treaty with particular emphasis upon the regime of freedom of exploration and use established under this treaty.

A class could discuss the *1968 Agreement on the Rescue of Astronauts, the Return of Astronauts, and the Return of Objects Launched into Outer Space. The Moscow Partial Test Ban Treaty of 1963* and the *Treaty on Liability for Damage Caused by the Launching of Objects into Outer Space* could be studied from documents.

Selected problems in the legal regulation of outer space activities.

Discussion here might focus upon certain aspects of space utilization which require legal

regulation. For example:

> Military uses of outer space, the problem of boundaries between the sovereign airspace and free outer space, the question of allocation of valuable resources found in outer space and on celestial bodies, optimal forms of international co-operation, problems relating to the establishment and operation of global, regional, and national satellite telecommunications networks.

Bloomfield, Lincoln. (Editor). *Outer Space: Prospects for Man and Society.* Englewood Cliffs, Prentice-Hall, 1962

Chapman, J.H. et al. *Upper Atmosphere and Space Programs in Canada.* Ottawa, Queen's Printer, 1967

Chaumont, C. *Le droit de l'espace.* Paris, Presses Universitaires de France, 1960. 128 p.

Cooper, John Cobb. *Explorations in Aerospace Law.* Montreal, McGill University Press, 1968

Drury, C.M. *White Paper on a Domestic Satellite System for Canada.* Ottawa, Queen's Printer, March 28, 1968

Goodwin, H.L. *The Images of Space.* New York, Holt, Rinehart and Winston, 1965

Kash, Don E. *The Politics of Space Co-operation.* Layfayette, Indiana, Purdue University Press, 1967

McDougal, M.S. et al. *Law and Public Order in Space.* New York, Yale University Press, 1963

Ramo, Simon. (Editor). *Peacetime Uses of Outer Space.* New York, McGraw-Hill, 1961. 279 p.
The story of outer space provides a symbolic and real example of scientific and technological change.

Science Council of Canada. *A Space Program for Canada.* Ottawa, Queen's Printer, 1967

Shternfeld, Ari. *Soviet Space Science.* New York, Basic Books, 1959

Staff Report for U.S. Senate Committee on Aeronautical and Space Sciences. *Soviet Space Programs: 1962-1965; Goals and Purposes.* Washington, U.S. Government Printing Office, 1966

Wilson, J.T. *IGY, Year of the New Moons.* Toronto, Longmans, 1961
Dr. Wilson, the Canadian geophysicist who travelled to every continent visiting scientists, describes the cooperation of the International Geophysical Year.

The Way into Space

One "pilot class" in space studies kept a record of the topics that were treated as the students traced the development of rocket-craft. Other classes might begin at any point in this list of events, and might choose any item for increased or reduced emphasis. The list is given below:

- first practical rocket of 1040 A.D.
- rocket attacks by Moors in 1349
- rockets used against British in India
- rockets with one mile range used in Napoleonic Wars and American Revolution
- rockets in 1800's to carry distress flares into air and to propel lifelines to ships
- Goddard, during World War 1, used solid-fuel rocket
- liquid-fuel rocket of 1920
- during World War II, the V-1 and V-2
- Americans developed Redstone, Jupiters, and Saturns for space exploration
- Canadians developed the Black Brant series for scientific use at Churchill
- methods of propulsion in rockets and Newton's Third Law
- types of fuels
- procedures to lift payload into orbit and to retrieve
- short history of satellites from Sputnik 1 to latest probe
- uses: Tiros and Nimbus for weather, Echo and Syncom for communications, Vostok and Apollo for manned flight, Lunik and Surveyor as lunar probes, Sputnik V and Mariner as planetary probes, Transit for guidance and Alouette for ionospheric information
- other uses: for detection of ocean depths, topography, military installations, mineral deposits, magnetic fields, and the shape of the earth.

Von Braun, Wernher and F. I. Ordway III. *History of Rocketry and Space Travel.* Chicago, J.G. Ferguson, 1966. 244 p.
This well-illustrated book contains material from original sources and a dozen pages of bibliography.

Great Ideas in Astronomy

The outlook of mankind probably has been affected more by changes in the concepts of astronomy than by changes in any other science. A new philosophy developed when a heliocentric planetary system replaced a geocentric system and man was no longer at the centre of the universe. Similarly, the discoveries of Kepler and Newton led to a different understanding of the meaning of scientific laws. The idea that man's complete knowledge of distant bodies has to come from a study of electro-magnetic radiation presented another challenge. The recognition of the nuclear energy of stars and their patterns of evolution further changed man's thinking. Over the centuries, a revolution in man's thinking has taken place.

Gauzit, J. *Les grands problèmes de l'astronomie.* Paris, Librairie Dunod, 1951

Hoyle, F. *Astronomy.* New York, Doubleday, 1962

King, H.C. *The Exploration of the Universe.* New York, Signet, 1964

Ley, W. *Watchers of the Skies.* New York, Viking, 1966

Portland Physical Science Project. *Designs of the Cosmos.* New York, Holt, Rhinehart and Winston, 1965. 206 p.
This physical science course contains several exercises and ideas that support classroom work in astronomy.

Struve, O. and V. Zebergs. *Astronomy of the 20th Century.* New York, Macmillan, 1962

Fiction About Space

Science fiction buffs may be found in surprisingly large numbers in this course. Their well-developed taste in science fiction can prove a challenge to other students. While the study and appreciation of the imaginative works of professional authors is a worthwhile activity, some students should themselves write fiction in prose, verse, or drama. Some may wish to use the 8mm. film as their medium and others tape for recording. In any case, students and teachers could decide whether to use a solid block of time for imaginative art, or to plan for an ongoing activity over a longer interval parallel to other studies.

Long ago men looked about and beyond themselves, and being unable to explain what they saw, invented explanations. Their early attempts to express solutions have come down to us in the myths and legends of many peoples.

The myths and legends, like those of the Greeks, Hebrews, and Indians, were attempts to explain the past and the present. Men did not stop there, however. Their curiosity about what might exist in the future, and their interest in weird and wonderful inventions led them to extrapolate the present into the future, to speculate, to raise problems and to suggest possible solutions. Thus was born the vast amount of science fiction.

Sometimes science fiction is primarily fantasy; at other times it describes that which reasonably might be. There are still other times when our lack of knowledge makes it difficult to distinguish the strictly fantastic from the merely improbable.

There are hundreds of appropriate books, written by such authors as Jules Verne, H.G. Wells, John Wyndham, Isaac Asimov, R. Heinlin and Clifford Simak.

In *The Black Cloud*, astronomer Fred Hoyle tells of the discovery of an obscuring cloud that turns out as an intelligent being. *The Voyage of the Space Beagle* by A.E. Van Vogt, may stimulate discussions on politics, government, and the problems of space flights. Arthur C. Clarke appeals to students because as a scientist he is able to base fiction on fact. His story of a future world controlled by a large computer complex is titled *The City and the Stars.* Written by D.F. Galouye, *Lords of the Psychron* deals with an earth invasion in which there is both a time and psychological problem. In *A for Andromeda,* the problem is a moral one. Ray Bradbury's *The Martian Chronicles* is already popular in many secondary schools.

While hardly science fiction, A.P. Herbert's whimsical *Watch This Space* will indicate other dimensions to space literature.

Opening the Windows

The portion of the electromagnetic spectrum that is represented by the optical window through which we observe the universe has been limited both by the atmosphere and by our earthbound instruments. Through the years meteoric material has been the only extraterrestrial matter available for direct study. Then it became possible to observe the effects of cosmic rays, those energetic particles from other parts of our galaxy. Now, sophisticated technology has greatly extended the means by which man can study the universe about him. Most important, he can now conduct experiments in space rather than merely observe the phenomena of space. In this context, the question of international co-operation is relevant.

Meteors: types and rates of influx, meteor showers, meteorites, meteor observations and the role of the amateur, radar observations, search for organic material, tektites

Cosmic rays: energy range, possible origins, observation, and effects

Radio and radar astronomy: penetration through "dust" of space, sources, Doppler shifts, struggle for resolution, observation of invisible surfaces of some planets

Orbiting observatories: advantages, stabilization problems, energy sources, range of observations

Interplanetary probes: orbits and launch times, information of particles, radiations and magnetic fields, the solar wind

International Co-operation: IGY, co-operative launchings at Churchill, co-operative use of satellites, distribution of satellite command stations and data collection centres, international storing of scientific data.

Berkner, L.V. and H. Oldishaw. *Science in Space.* New York, McGraw-Hill, 1961

Dauvillicr, A. *La poussière cosmique.* Paris, Masson, 1961. 207 p.
While formerly cosmic space was considered to be absolutely empty, today more and more one considers it as filled with particles and vapours.

Le Galley, P.P. *Space Science.* New York, Wiley, 1963
Each chapter has a list of specific and general references.

Smith A.G. and T.D. Carr. *Radio Exploration of the Planetary System,* Princeton, Van Nostrand, 1964
This book, also available as a Momentum paperback, is a complement to the F.G. Smith listing.

Smith F.G. *Radioastronomy.* Harmondsworth, Pelican, 1962
An excellent account written with intelligence and style.

Stcinbcrg, J.L. et J. Lequeux. *Radioastronomie.* Paris, Libraire Dunod, 1963

Rocketry

Some students may be interested in the engineering and technical aspects of professionally launched rockets. Some may be interested in the individual probes launched in Canada and elsewhere. Some may be interested in model rocketry.

The last group must be guided by the booklet *Approved Regulations for Rocketry by Amateurs in Canada* from the Royal Canadian Flying Clubs Association, Suite 207, 2277 Riverside Drive East, Ottawa 8, Ontario. This booklet was prepared by the Canadian Aeronautics and Space Institute.

Model rockets are constructed of balsa wood and other light materials with the total weight never exceeding one pound. The descent is slowed down by a parachute or other means, so that no injury or damage can be caused. The rocket engines, which must be commercially made and of an approved design, must not contain more than four ounces of propellant. As a further safeguard, the combustible chemical mixtures that form the propellant may only be manufactured in a factory operating under the Explosives Act.

Conditions have been set for launching rockets. No one may launch a model rocket:

(a) within ten miles of an airport
(b) in a manner likely to create a hazard to aircraft
(c) in any manner that creates or is likely to create a hazard to persons or property on the ground
(d) into any cloud
(e) to a height greater than 1200 feet above ground level
(f) unless a firing supervisor, approved by the Royal Canadian Flying Clubs Association or the Canadian Association of Rocketry, is present to supervise the launch.

Model Rocketry

Miniature rocket engines are available from commercial sources, and model rockets may either be purchased or made by hand. According to one source, there were 3170 active rocketeers in Canada in 1969. While highly skilled personnel, following safety regulations, launch space probes for scientific purposes regularly in Canada from restricted areas, *no teacher should allow the testing or launching of rockets except with explicit permission of the proper authority and in conformity with local and federal regulations.* It should be noted that no one under the age of seventeen years may participate in the static or ground testing of rocket engines or the launching of rockets without the written consent of his parent or guardian.

Theory of Rocket Engines

Students will encounter such terms as propellants, fuel consumption, thrust, power, specific impulse, and efficiency. Much can be learned from tests with water rockets.

Trajectories and Orbits.

Ballistic rockets, orbital rockets, lunar rockets, and interplanetary rockets may be studied in respect to propulsion, navigation, and re-entry.

Blosset, Lise. *Les fusées expérimentales, moyen auxiliaire d'enseignement.* A paper presented at the Warsaw Conference in September, 1964, by Mademoiselle Blosset, Directeur de la Division des Relations Universitaires du CNES, 129 rue de l'Université, Paris 7(e), France.

Brinley, B.R. *Rocket Manual for Amateurs.* New York, Ballantine Press.

Hertz, Louis H. *The Complete Book of Model Aircraft, Spacecraft and Rockets.* New York, Crown, 1967. 278 p.
About selecting, building, flying and launching craft with safety.

Stine, G. Harry. *A Handbook of Model Rocketry.* Chicago, Follett, 1967. 304 p.
A comprehensive book about how to build and launch model rockets safely, including calculations for design and tracking.

Probing the Upper Atmosphere

This section on the upper atmosphere emphasizes those aspects where the data has been obtained from space probes, either satellites or rockets. It is important that the necessary background be included so that the student will be in a position to find patterns in the phenomena. Background can be secured in either of two ways. Sometimes teachers prefer to provide background in logical fashion to prepare students for difficult items. Sometimes teachers prefer to provide background when the need becomes evident.

Undisturbed upper atmosphere

(a) Density and temperature profiles
(b) Composition profile
(c) Winds and tides
(d) Ionosphere: (i) regions
(ii) effect on radio communications

Disturbed upper atmosphere

(a) Aurora
(b) Solar flares
(c) Effect of solar flares on upper atmosphere:
(i) sudden ionospheric disturbances
(ii) polar cap absorption events

Berkner L.V. and H. Oldishaw, *Science in Space.* New York, McGraw-Hill, 1961
A comprehensive account of the science in space with considerable detail and many references.

Craig, Richard A. *The Edge of Space.* (Science Study Series) New York, Doubleday, 1968. 150 p.
The upper atmosphere and its exploration is described by a meteorologist.

Hines C.O. et al. *Physics of the Earth's Upper Atmosphere.* Englewood Cliffs, Prentice-Hall, 1965

Scientific American. *Offprints.* Available from W.H. Freeman and Co., 660 Market Street, San Francisco, California, 94104 as follows:
#248 Radiation belts around the Earth by James A. Van Allen (March 1959)
#851 Artificial satellites and the Earth's atmosphere by Robert Jastrow (August 1959)
#858 The Antarctic and the upper atmosphere by Sir Charles Wright (September 1962)
#873 The Shape of the Earth by Desmond King-Hele (October 1967)

Further Themes for Student Choice

In a course as open as this, there are hundreds of possible themes related to the domain of space. Here some twenty are suggested, but from the very first day, students and teachers can be looking for additional ones.

Some teachers may encourage "far out" ideas in space and astronomy. Youth may find links with philosophy as they echo Piet Hein, "I'd like to know what it's all about before it's out." Some young people with a bent toward language may want to read Tsiolkovsky in the original Russian. Some may have deep but narrow interests in sunspots or the aurora.

Students may find experts in meteorology or model plane construction in their own community. Such chance opportunities may introduce new themes, just as a visit to an aerospace institute or other establishment may open eyes to new fields.

Where a theme is specially selected by a group or by a single student, it should be counted as one of the themes in the curriculum. If it were counted as an extra theme, the burden might become unreasonable.

The Impact of Space on Humanity

Man has placed new moons circling around the earth and new bodies orbiting the sun like planets. The everyday life of man is being altered by the events of space. The daily press describes the conquest of space by man, but only slowly is there recognition that man himself is being affected in the process.

Students interested in economics can trace the growing prosperity of segments of population producing space hardware and the serious deprivation of other segments that results when a significant fraction of a nation's labour and money is devoted to non-productive activities. Supra-national institutions have grown with space achievements with a concurrent lessening of the nationalism that has so often fostered arts and other creative activity. The man in the street has a voice that is less frequently heard; yet unless he understands the space world and becomes involved, decisions which affect him for good or ill will be made by others. Space activities and space technology may have a critical role in determining for Canadians their well being, their independence, and the fulfilment of their aspirations.

Chapman, J.H. et al. *Upper Atmosphere and Space Programs in Canada.* Ottawa, Queen's Printer, 1967. 258 p.

Evans, F.T. and H.D. Howard. *Outlook on Space.* London, Allen and Unwin, 1965

Fallaci, Oriana. *If the Sun Dies.* New York, Atheneum, 1966. 403 p.
This Italian woman writer describes the effects of the space program on the lives of the NASA astronauts and scientists, as well as the human race in the future.

Gamow, G. *Infinity 1,2,3,.* New York, Viking Press, 1947. 340 p.
A nuclear physicist writes about facts and speculations against a background of mathematics and science.

Gordon, T.J. *The Future.* New York, St. Martin's Press, 1965. 184 p.
An engineer extrapolates from today's world into the world of tomorrow with its pitfalls and promises.

Herbert, A.P. *Watch This Space.* London, Metheun, 1964

Hirsch. Lester M. (Editor.) *Man and Space.* New York, Pitman 1966. 202 p.
Avoiding articles too technical and too temporal, the editor asks whether we are wasting resources or moving to the threshold of change.

Kash. Don E. *The Politics of Space Cooperation.* Lafayette, Indiana, Purdue University Studies, 1967

Canada's Contribution in Space

Upper atmosphere studies include studies of the ionosphere, stratosphere, magnetism, the Van Allen belts, the solar wind, and the aurora. A significant fraction of the new knowledge concerning the outer reaches of our atmosphere and its interaction with the atmosphere of the sun can be gained by observations made in and near the auroral zone. Canada is the only large land mass from which probes into the auroral zones can be readily launched.

Solid-propellant research has been carried on since 1956, and the first of the Black Brant rockets was launched in 1959.

The Churchill Research Range with its ground stations has long been known as a center for studies of the aurora and related ionospheric and upper atmospheric topics. Alouette I, designed wholly by Canadians, was launched in 1962, to be followed by another Alouette in 1965, and Isis A in 1969. Ground stations are located at Ottawa, Thompson, Churchill, and Great Whale and other places.

Large radiotelescopes are located in Penticton and Algonquin Park, while the larger optical telescopes are housed in observatories at Ottawa, Richmond Hill, and Victoria.

Chapman, J.H. et al. *Upper Atmosphere and Space Programs in Canada.* Ottawa, Queen's Printer, 1967. 258 p.

King, Henry C. *The McLaughlin Planetarium.* Toronto, Royal Ontario Museum, 1968. 76 p.
This booklet introduces the reader to astronomy and briefly describes the development of astronomy in Toronto.

Northcott, Ruth J. (Editor). *Astronomy in Canada.* Available from Royal Astronomical Society of Canada, 252 College St., Toronto 130. 1967. 132 p.
Nine articles discussing the history of astronomy in Canada up to the Centennial year.

Applications of Mathematics

Most of the laws and principles that make space exploration understandable are most easily expressed in the language of mathematics. For those fluent in mathematics, there are many space ventures and many astronomical events for discussion. Scientists have developed models to describe the motion of bodies in space. Mathematics can be linked with the study of ballistics and trajectories. Similarly, rocket propulsion and aircraft flight can be described in mathematical terms.

Ahrendt, M.H *The Mathematics of Space Exploration.* New York, Holt, Rinehart and Winston, 1965

Meitner, John G. (Editor). *Astronautics for Science Teachers.* New York, Wiley, 1965
Ten authors discuss special fields of science in relation to space travel. The concluding chapter suggests methods, and lists teaching aids.

Origins

Cosmogony concerns the great central problem of the origin and evolution of the earth, planets, sun and the solar system - a problem not entirely solvable. Planetary probes and radar astronomy have added to the information gathered by earth-based optical instruments investigating the problem. Though we may observe stars and galaxies in the making, and stars and galaxies in different stages of evolution, it is not easy to put the pieces together. The attempt to know the content and organization of the universe as a whole forms the most difficult challenge, but theories have been developed to describe the picture of the world as it is and as it may be in the future.

The contributions of the largest instruments, both optical and radio, earth-based and moonbound, will be needed to provide pieces for the puzzle. Ties may be found to quasars, Seyfert galaxies, neutron stars, and high energy phenomena.

Bergamini, David. *Universe.* New York, Time-Life, 1966. 192 p.
This description of the universe from planet to galaxies reaches back into history, yet includes current thought. Well illustrated, the book avoids mathematics.

Bonner, W. *The Mystery of the Expanding Universe.* London, Eyre & Spottiswoode, 1965. 224 p.
No previous knowledge of the subject and no mathematics is required to follow the cosmological models described.

Gamow, G. *La création de l'univers.* Paris, Dunod, 1961

Lovell, Sir Bernard. *Our Present Knowledge of the Universe.* Cambridge, Harvard University Press, 1967

Marquand, John. *Life: Its Nature, Origins and Distribution.* Edinburgh and London, Oliver and Boyd, 1968. 96 p.
Questions of the origins, antiquity, and distribution of life are considered.

Munitz, M.K. *Theories of the Universe.* Glencoe, Free Press, 1957

North, J.D. *The Measure of the Universe.* London, Oxford University Press, 1965. 464 p.

Page, T. and L.W. Page. *Origin of the Solar System.* New York. Macmillan, 1966

Reddish, Vincent C. *Evolution of the Galaxies.* Edinburgh and London, Oliver and Boyd, 1967. 119p.
Based on published research of many astronomers, the book describes galaxies through words, sketches, photographs and numbers.

Sadil, Josef. *Our Planet Earth.* London, Hamlyn, 1968. 190 p.
Printed in Prague, this artistic book depicts the origins of today's Earth.

Communication by Satellite

The General Assembly of the United Nations has set down the principle that communications by means of satellites should be available to all nations of the world as soon as practicable on a global basis without any discrimination. Communication by satellite may make a major contribution to world peace and to understanding between peoples.

- Electro-magnetic wave propagation
- The communications satellite
- Satellite power supplies
- Passive and active communication satellites
- Ground stations
- The future of communication satellites for Canada

Dwiggins, Don. *Voices in the Sky.* San Carlos, California, Golden Gate Junior Books, 1969. 80 p.
A well-illustrated story of communication satellites designed for a young reader.

Jaffe, Leonard. *Communications in Space.* New York, Holt, Rinehart and Winston, 1966. 176 p.

The Planets

The planets lend themselves readily to practical work. Observations with even a small telescope reward the student. Planetary study may form a starting point for several kinds of exploration. Some students may look into problems of inter-planetary flight. Others may become interested in the astronomer's continual struggle for information.

The student who observes Mars with a three-inch refractor, who examines early photographs of its disc, and who then sees the surface as it was discovered by Mariner 6, appreciates the limitations under which astronomers have worked. Students will have their own questions, such as "Is there a planet beyond Pluto"? and "Where did the planets come from"?

de Gallatay, Vincent et A. Dollfuss. *Atlas des planètes.* Paris, Gauthier Villars, 1968. 167 p.
A true work of art.

Firsoff, V.A. *The Interior Planets.* Edinburgh and London, Oliver & Boyd, 1968. 117 p.
This short book covers much of our limited knowledge of the planets Mercury and Venus.

Guerin, Pierre. *Planètes et satellites: monde de l'espace.* Paris, Larousse, 1967. 306 p.
This work discusses the physical constitution of the planets and the possibility of life at their surface.

Leonard, J.N. and C. Sagan. *Planets.* New York, Silver, 1966

Ohring, George. *Weather On the Planets.* (Science Study Series), New York, Doubleday, 1966. 144 p.
This paperback describes how information on planetary atmospheres is secured.

Page, T. and L.W. Page. *Neighbors of the Earth.* New York, Macmillan, 1965. 336 p.
This anthology of the discoveries that describe planet surface characteristics emphasises the space probe contribution.

Sagan, Carl et al. *Planets.* New York, Time, 1966. 200 p.
Through text and pictures the astronomer-author discusses the origin, composition, atmospheres, and surfaces of the planets.

Whipple, F.L. *Earth, Moon and Planets.* Cambridge, Harvard University Press, 1968

Science and Technology

Is the flight of a plane or rocket a problem in technology or science? Such a question would lead to further questions about science and the purposes of scientists and the scientific community, or questions about technology, its functions and the technological community. Students should not leave the secondary school afraid of science or unconcerned about the relevance of the impact of science and technology on our society.

Holton, Gerald. (Editor). *Science and Culture.* Boston, Houghton Mifflin, 1965. 348 p.
A whole spectrum of divergent views has been brought together to treat the complex problems of science, technology and the humanities.

Are We Alone?

The basic biological question of the existence of extra-terrestrial life is one of considerable fascination for many young people. There are several starting points for a study of the question. The reading of a piece of science fiction about extra-terrestrial life is one effective way to begin. Another way to start would be to study the precautions taken to prevent astronauts from contaminating space with our bacteria and to prevent future space explorers bringing back organisms against which we have no defenses. Yet another introduction to the topic might come from a student's interest in the nature of unidentified flying objects. Student activities might include:

(a) Exploring the origin of biological chemicals by duplicating the earth's early atmosphere and producing amino acids by electrical discharge.

(b) Examining the doctrine of "Spontaneous Generation of Life" by repeating Pasteur's experiment.

(c) Constructing models to exemplify experiments on extra-terrestrial life such as the Wolf-Trap or Project-Osma signal patterns.

(d) Combining fact with fantasy in depicting an extra-terrestrial creature through words, sketches or three-dimensional models.

Bray, A.R. *Science, the Public and the UFO.* Ottawa, Bray Book Service, 1967. 193 p.

Gillmor, Daniel S. (Editor). *Scientific Study of Unidentified Flying Objects.* Bantam, 1969
This report produced by the University of Colorado under Dr. Edward H. Condon contains many sketches and photographs.

Macgowan, Rogers A. and F. Ordway. *Intelligence in the Universe.* Englewood Cliffs, Prentice-Hall, 1966. 402 p.
A comprehensive analysis of what life could exist beyond the Solar System - from the search for primitive life forms to empirical evidence of super intelligence.

Ovenden, M. *Life in the Universe.* Anchor, 1962

Shklovskii, I.S. and Carl Sagan. *Intelligent Life in the Universe.* San Francisco, Holden-Day, 1966
Soviet and American scientists collaborated in summarizing the possibility of extraterrestrial life.

Sullivan, W. *We Are Not Alone.* New York, McGraw-Hill, 1966 (revised)
Useful for examining the idea that other civilizations might exist elsewhere in the universe.

IMPLEMENTING THE LOCAL PLAN

Determining the Program

A sense of accomplishment and satisfaction will be a student's reaction when he finds that *Space and Man* answers his needs. Because the course, as written here, has no predetermined objectives, and because there is a broad range of themes, many of his needs can be met. But to find the needs of the students, their expectations and their aspirations, student co-operation must be sought right from the start.

Knowledge is important, but there is no minimum that is essential, nor any maximum limit. It does not matter whether the student can define specific impulse or can list values for the albedo for the planets. It does matter that *Space and Man* in his school contributes toward making the world understandable and his place in that world reasonable. As soon as possible, students should meet with their teachers to assess what is possible and to decide which themes promise most.

The great advantage of a course that straddles the disciplines and is not confined, lies in the opportunity for exercising responsibility. Since the program does not follow the conventional disciplines there is a wide opportunity for choice. No one student and no teacher can foresee the type of program that will evolve during the year. The group will be able to modify the program, and continually remain responsible for the decisions.

Sharing the Teaching

Since the themes of this course lead into many disciplines, students will be looking for guidance in a broad range of activities. One teacher with a wide experience may be able to give the general guidance needed, but for items beyond his special competence, he may seek assistance from colleagues. Almost every teacher has colleagues whose knowledge and experience would support parts of the course. In some circumstances, experts from outside the school could contribute to class or seminar work.

Shared teaching may be organized in many ways. In some cases teachers may simply trade classes for the required number of periods, although this may result in undesirable fragmentation and lack of continuity in the course. In other cases, individual students may be referred to the teacher whose special competence coincides with the student's special interest. In still other places teachers might jointly prepare and guide class activities, in a way that could leave one class working independently with a minimum of direct supervision while a second class was benefiting from the interaction of the association with two teachers.

Clearly, there are advantages where several teachers work co-operatively, but the advantages are likely to disappear if each teacher, in becoming responsible for a theme, works in isolation.

Three Ways for One Theme

When a theme such as "Introduction to Flight" has been chosen, how is the topic taught? First of all, the teacher will remember the reasons that the topic was chosen. Some of them will have been voiced, but there will be other reasons only dimly formulated to which the adult will be sensitive. The teacher has his reasons for the choice too, for without his concurrence, consensus could not have been made.

Next, the teacher will seek the aspect of the theme that may be most rewarding for young people. As an adult, he knows the many curriculum paths through the academic forest. Each leads to a destination. No way is clearly best, for adventure and challenge

might be found on any route. But depending on the teacher, the class, the facilities, and the goals, a choice must be made.

For example, some students might want to interpret the phenomenon of flight as the unrolling of history, here titled *The Story of Flight.* Some students might want a science-oriented theme, which is called here *The Science of Flight* and which can include much aerodynamics. Still others with a sensitivity to the human condition might prefer a people-oriented course, *The Challenge of Flight.*

Many themes in the syllabus can be treated in many ways. The three examples that follow are inserted as models. Each is a variant of one theme, "Introduction to Flight".

Introduction to Flight (Example A)

THE SCIENCE OF FLIGHT – SCIENCE ORIENTED

1. Beginnings of Aerodynamics
The earliest projectiles, Aristotle and the motion of projectiles, Leonardo da Vinci's aerodynamics, fluid mechanics in modern science, the progress of flying from the eighteenth century onwards

2. The Problem of the Resistance of the Air
Air resistance in ballistics, the theory of fluid resistance, the wake behind a body and its significance, the effect of viscosity on resistance, skin friction and the boundary layer, the resistance at moderate speeds

3. The Problem of Resistance and Turbulence
Turbulence, the Reynolds number, the nature of turbulence circulation, vorticity and the formation of eddies, the effect of turbulence on resistance, drag coefficients, the physical significance of the Reynolds number

4. The Theory of the Wing
The historical development of the aerofoil, the Magnus effect, aerofoils, the analysis of lift, induced drag and its significance, propellers and windmills

5. Stability in Flight
Static and dynamic stability, the theory of aircraft stability, tailless aircraft

6. The Aerodynamic Problems of High Speed Flight
Compressibility, shock waves, lift and drag at high speeds, the design problems of high-speed aircraft, aerodynamic heating at high speeds

7. The Ultimate Flying Machine
The history of rockets, the principle of the rocket, aerodynamic problems in rocket design, jet propelled aircraft, giant rockets and the problems of escape from the earth

8. The Tools of Aerodynamics
Activities with: bow and arrow, paper aeroplane, boomerang, viscosity experiment, Bernouilli's experiment, Reynold's experiment, water tunnel, wind tunnel, simple wind tunnel balance, models for wind and water tunnels, rotor ship, model aeroplane.

Introduction to Flight (Example B)

THE CHALLENGE OF FLIGHT – PEOPLE ORIENTED

1. Looking to the Stars
The emotional appeal of flight, myth, religion and legend, the prophets, the creation of air-mindedness.

2. The Adventurers and the Dreamers
Early attempts at flight, the first designers, bird flight, the need for science

3. The Balloonists
Lighter than air flight, the first manned flight 1783, the first hydrogen balloon 1783, Andree's North Pole attempt, the golden age of ballooning 1901-1910, balloons at war (the observation balloon and the barrage balloon)

4. The Air Sailors
The first airships, airships at war (the Zeppelins, the Zeppelin-killers), the British R Ships, the U.S. naval airships, the German commercial airships, the reasons for failure

5. The Gliders
Gliding flight, soaring flight, gliders at war, modern gliding

6. The Heavier than Aeronauts, 1903-1914
The designer-pilots, those magnificent men in their flying machines

7. The Aces, 1914-1918
The aeroplane at war, the development of air fighting, the Canadian aces

8. The Commercial Fliers 1918-1939
The development of modern commercial aviation, the record breakers

9. The Few and the Many, 1939 - 1945
The fighters, the bombers, the ship hunters, the Empire Air Training Scheme, carrier fliers, transport operations

10. The Jet Set
The jet engine, the test pilots, Mach I, the frontier of space, the X15, the supersonic airliner

11. The Astronauts
The first Russian flights, Mercury, Gemini, Apollo, and after

Introduction to Flight (Example C)

THE STORY OF FLIGHT – HISTORY ORIENTED

1. The beginnings of flight
The earliest projectiles, ambitions towards flight, balloons, kites, gliders, the internal combustion engine, powered flight

2. The early days
Pioneer flights, early use of aircraft in War (1914-1918) the beginnings of civil aviation in the Twenties.

3. The transition period
The Thirties with the global airways and the accelerated development of military aircraft; the advent of jet and rocket-propelled aircraft during the Second Great War

4. The jet age
Military developments, the helicopter, VTOL and STOL, civil developments, the high-subsonic transport, the supersonic transport, the Jumbo jet

5. Operational problems
Flight safety, air traffic control, the sonic boom, navigation

6. Space flight
The first Russian flights, rivalry in U.S.A. programs in other countries, co-operation in space

7. The Shape of the Future
From the Apollo program to outer space

Assessment

It is difficult to visualize the application of conventional evaluation devices to this unconventional course. In *Space and Man* different classes will select different themes, several teachers may staff the program, or students may be making independent studies. Assessment would be easier if all students followed the same program. But a uniform program negates the premise that students should make their own choice of course. One objective underlies the course. Each student will be trying to achieve a better understanding of space than he had before.

The problem, therefore, becomes the problem of finding the degree of improvement in understanding, not the absolute measure of what is understood. Tests and examinations are blunt instruments of assessment compared to the daily conversation of teacher with pupil about the work, or the discussion of a report on an experiment between student and teacher or student and student. Perceptive teachers can observe the students as they go about their own tasks from day to day. Sensitive teachers can devise open-book examinations with many options, so that every student finds the challenging ones in which he can show his achievements. If pieces of work are retained in a file and then examined from month to month, change can be observed.

Sometimes the importance of self-evaluation goes unrecognized. Every student will be evaluating his progress continually, whether he is designing a kite, examining the shadows of lunar mountains on astronomer's photographs or writing a paper in defence of expenditures on space research. Yet he will look to his teacher to corroborate his subjective opinion, or to moderate his own estimate.

The suitability of the chosen course and the effectiveness of the teaching is also under evaluation. Teachers will be evaluating the whole operation continually, using for a yardstick both the degree of effort of their students and the degree of empathy that has sprung up within the class group.

Student Projects

The purpose of projects and research ventures is to give the student many occasions when he can work in the most free fashion to produce something that gives him satisfaction.

Although the individual's project often brings the best out of a student, class projects have considerable value too. For example, a whole class can co-operate in making a meteor count around the time of a meteor shower, or join in the enterprise of making a commemorative mural when a Canadian satellite is being launched.

Students usually prefer to work alone or in twosomes. Small groups of two or three are sometimes needed in making astronomical observations.

Some teachers encourage project work by beginning research ventures of their own at school. Curiosity is quickly aroused and soon students come with many requests for suggestions and advice. Teachers may find that students will be asking the following:

Where are suitable references? How is the information put together? Where can components and supplies be found? How can mechanical, electrical or electronic faults be found and corrected?

The project idea breaks down unless it is considered a part of the course. If a project is worth doing, it is worth doing in scheduled time. In some schools, a block of several weeks is timetabled just for this purpose. This measure also obviates a time conflict between longterm out-of-class assignments and the chosen project.

The preliminary discussions and the informal conversation that accompanies the work are probably as important as the constructive activity and its report. Students must make their own decisions. They must decide what to do, how much time to budget for the project and how much money to spend. It is always a good idea to discuss cost and stress the fact that often the most expensive project is not necessarily the best. The project made on a small budget with maximum utilization of "around the house material" is usually more educational than one involving the purchase of expensive "ready made" components.

Because the course is not oriented to cover any specific discipline, long-term class assignments, and projects for individuals and groups will likely replace short-term daily assignments in this course. The inquiry and project method as approaches to class

participation are recommended because they permit all students to become involved to the limit of their individual abilities.

Here is a list of devices that came from a "pilot class" whose members had good access to work benches, tools and materials:

Model of Alouette I
Solar cooker
Modulated light beam transmitter and receiver
Water propulsion rocket
Hand-held astrolabe
A refractor
A reflecting telescope
Solar meter

Here are some topics that were used as a basis for research projects where a class had good workshop and library facilities:

Algae as food
Protozoa and space
Fuel cells
Cosmic rays
Our sun
Rocket engines
The planets
Launch vehicles
Fingerprints of stars
Oxygen for space vehicles
Life in a closed system

Groups of students, in rotation, may undertake the major project of recording what has happened during the whole term or year. Already some pilot classes have made scrapbook journals from the columns of the daily newspaper. Others have prepared films on contemporary commercial aircraft, rocket landings and eclipse phenomena. Some have made diaries of day-to-day class activities. Such long-term records prove interesting to students within the school, and to others beyond. In a course such as *Space and Man,* every class becomes a pioneer group with a unique experience to be shared with other pioneering schools.

RESOURCES

Periodicals

Air et Cosmos, published weekly at 21, rue d'Uzès, Paris (9e), France.

Canadian Aeronautics and Space Journal, published monthly September to June by the Canadian Aeronautics and Space Institute, Commonwealth Building, 77 Metcalfe St., Ottawa 4.

Canadian Aviation, published monthly by Maclean-Hunter Publishing Company, 481 University Avenue, Toronto 101.

Canadian Scientist, published bi-monthly by Pergamon of Canada Ltd., 207 Queen's Quay West, Toronto 117.

New Scientist, published weekly by New Scientist, 128 Long Acre, London W.C.2.

La Recherche Spatiale, published monthly by Dunod, 92 rue Bonaparte, Paris (6e), France.

Royal Astronomical Society of Canada Journal, published bi-monthly by the Royal Astronomical Society of Canada, 252 College St., Toronto 130.

Science et Vie, published monthly from 5, rue de la Baume, Paris (8e), France.

Science Forum, published bi-monthly by the University of Toronto Press, 63A St. George St., Toronto 181.

Science in Action, published fortnightly by New Science Publications, 128 Longacre Road, London W.C. 2, England.

Scientific American, published monthly by Scientific American Incorporated, 415 Madison Avenue, New York, N.Y., 10017.

Sky and Telescope, published monthly by Sky Publishing Corp., 49 Bay State Road, Cambridge, Mass. 02138.

Skylights, published nine times a year by National Aerospace Education Council, Suite 616, Shoreham Bldg., 806, 15th St. N.W., Washington, D.C. 20005

Spaceflight, published monthly by the British Interplanetary Society, 12 Bessborough Gardens, London S.W.1, England.

Books

Abell, G.O. *Exploration of the Universe.* New York, Holt, Rinehart and Winston, 1964

Ake, Wallenquist. *Dictionary of Astronomical Terms.* New York, The Natural History Press, 1966. 265 p.
This paperback by a Swedish astronomer has 1700 entries.

Allward, Maurice. (Editor). *The Encyclopedia of Space.* Paris, Les Editions Rombaldi, 1967. 831 p.
A mature treatment of many topics associated with space exploration.

Alter, D. *Lunar Atlas.* Mineola, Dover, 1968

Amis, Kingsley. *New Maps of Hell.* London, Victor Gollancz, 1960. 141 p.
The book surveys the characteristics of science fiction in the past, present and future.

Asimov, Isaac. *To the Ends of the Universe.* New York, Walker, 1967. 136 p.
A comprehensive survey of the universe and its origin.

Barter, A.F. *Untravelled Worlds.* London, Macmillan, 1966. 166 p.
The twelve stories form a balanced anthology of science fiction for school use.

Bates, D.R. *The Planet Earth.* Oxford, Pergamon, 1964. 370 p.
Fifteen distinguished authors have made contribution for non-specialist readers in the specialized fields of the ionosphere, meteors, genesis of life, and the origin and fate of the Earth.

Berlage, H.P. *The Origin of the Solar System.* Oxford, Pergamon, 1968. 144 p.
The author describes many hypotheses that have been put forward during the past three hundred years.

Boischot, André. *La radioastronomie.* Paris, Presses Universitaires de France, 1965. 128 p.
Radio astronomy in space is just in its beginning stages, but it will likely complement observations made from earth.

Bray R.J. and R.E. Loughhead. *Sunspots.* London, Chapman and Hall, 1964. 320 p.
This comprehensive treatise should be available to students as an example of the highly specialized book.

British Astronomical Society. *Handbook.* British Astronomical Society, Hounslow West, Middlesex, England. Annual.

Brown, Sam. *All About Telescopes.* Available from Edmund Scientific Co., 101 E. Gloucester Pike, Barrington, New Jersey, 08007.

Butler S.T. and H. Messel. (Editors). *Light and Life in the Universe.* Oxford, Pergamon, 1965
Based on a summer school for fourth-year high school students in Sydney, the lectures deal with the possible origins of life on earth, and the possibility of life on other planets.

Cachon, A. et al. *Cosmic Rays.* New York, Walker, 1957. 129 p.
This translation is a brief survey of the field that includes mathematical treatment.

deCallatay, Vincent. *Atlas of the Moon.* London, Macmillan, 1964. 160 p.
Contains twenty-one plates with facing maps along with other lunar information.

Department of Transport. *Weather Ways.* Ottawa, Queen's Printer.
Well illustrated, the booklet outlines meteorology for airmen.

Emde, Heiner. *Conquerors of the Air.* New York, Viking, 1968. 201 p.
The illustrations by Carlo Demand, and Emde's vivid accounts portray the evolution of aircraft from 1903 to 1945. Specifications and scale drawings make this a rich data source.

Fielder, Gilbert. *Lunar Geology.* London, Lutterworth, 1965. 184 p.
First, Dr. Fielder supported the view that the crater-pitted surface was due to meteoritic bombardment but later he was convinced of its volcanic origin.

Firsoff, V.A. *Strange World of the Moon.* New York, Basic Books, 1959.

deGaliana, Thomas. *Dictionnaire de l'astronautique.* Paris, Librairie Larousse, 1964. 320 p.
This book presents many technical terms used in space ventures.

Gamow, George. *Gravity.* New York, Doubleday, 1962. 157 p.
The fourth chapter describes planetary orbits.

Gamow, George. *Naissance et mort du soleil.* Paris, Dunod, 1960. 176 p.
The book probes many of the secrets of the universe.

Gamow, George. *Une étoile nommée soleil.* Paris, Dunod, 1966. 176 p.
A description of the sun in the light of recent work of physics and astrophysics.

Gastrow, Robert. *Red Giants and White Dwarfs.* New York, Harper and Row, 1967

Gatland, K.E. and D.D. Dempster. *The Inhabited Universe.* London, Wingate, 1957. 182 p.
The speculation about the dawn of life leads back to the beginnings and ahead to the search for meaning.

Gauzit, J. *Les grands problèmes de l'astronomie.* Paris, Dunod, 1957. 184 p.
A survey designed for the reader who has no special acquantance with the great scientific progress of recent years.

Gauzit J. *La vie et la mort des étoiles.* Paris, Presses Universitaires de France, 1963. 122 p.

Glasstone, Samuel. *Sourcebook on the Space Sciences.* Princeton, Van Nostrand, 1965. 960 p.
This semi-technical book was written in cooperation with NASA.

Greenwood, J.R. *The Parachute - From Balloons to Skydiving.* New York, Dutton, 1964. 183 p.
The development of parachuting and the deeds of parachutists are described.

Hawkins, G.S. *Meteors, Comets and Meteorites.* New York, McGraw-Hill, 1964
This authoritative book contains useful problems to aid the teacher.

Hess, W.N. (Editor). *Introduction to Space Science.* New York, Gordon and Breach, 1965
This book has a considerable amount of information.

Hoskin, Michael A. *William Herschel and the Construction of the Heavens.* London, Oldburne, 1963. 199 p.
Sketches and interpretive papers of Herschel reveal this giant among astronomers.

Hoyle, F. *La cinquième planète.* Paris, Dunod, 1965. 220 p.
A science fiction novel written by a great astronomer.

Hoyle, F. *Le nuage noir.* Paris, Dunod, 1962. 223 p.
The book is the first novel of this astronomer who is well known all over the world.

Hoyle, F. *Le premier octobre il sera trop tard.* Paris, Dunod 1968. 195 p.
Explanatory notes accompany the translation of the English novel.

Hyde, Frank W. *Radio Astronomy.* London, Weidenfeld and Nicholson, 1962. 144 p.
The story of the newest branch of astronomy written for the young school scientist.

Inglis, Stuart J. *Planets, Stars and Galaxies.* New York, Wiley, 1961.

International Space Science Symposium (Third). *Life Sciences and Space Research.* Amsterdam, North-Holland Publishing, 1963. 184 p.
Life in cosmic space is described by Glenn, Titov, and others.

Johnson, J.E. *Wing Leader.* New York, Ballantine, 1967

King-Hele, D. *Observing Earth Satellites.* London, Macmillan, 1966
Useful for practical aspects of this course.

King, Henry C. *Pictorial Guide to the Stars.* New York, Crowell, 1967

Kopal, Z. *Exploration of the Moon by Spacecraft.* Edinburgh and London, Oliver and Boyd, 1968. 88 p.
A beautifully-illustrated short book on lunar space research.

Kuentz, Craig. *Understanding Rockets and Their Propulsion.* New York, Rider, 1964

Lachnitt, Jacques. *L'astronautique.* Paris, Le Rayon de la Science, 1962. 189 p.

Lewis, C.S. *Out of the Silent Planet.* London, Pan Books, 1960.
This first book in a trilogy has strong philosophical and theological undertones.

Ley, W. *Watchers of the Skies.* New York, Viking, 1966.
A good one-volume introduction to the ideas of astronomy and the men at the frontier of knowledge.

Lovell, Bernard. *The Story of Jodrell Bank.* London, Oxford University Press, 1968. 265 p.
A vivid account of a visionary's battle to realize a dream.

Lundquist, Charles A. *The Physics and Astronomy of Space Science.* New York, McGraw-Hill, 1966. 116p.
Since space science is quantitative, some mathematical developments have been included in this volume.

Macmillan, N. *Tales of Two Air Wars.* London, Bell, 1963. 272 p.
A series of stories about ordinary fighting men.

Macmillan, N. *Wings of Fate.* London, Bell, 1967. 191 p.
About the flying experiences of Macmillan in the early years of civil aviation.

Mansfield, Roger. (Editor). *The Starlit Corridor.* Oxford, Pergamon, 1967. 160 p.
This anthology of modern science fiction, short stories and poems provides dramatic comment on contemporary social issues.

Manuali, Bertrand. *L'exploration spatiale.* Paris, Hermann. 216 p.
This provides for technicians and for young people the necessary information for understanding the greatest adventures undertaken by man.

Massey, H. *Space Travel and Exploration.* London, Taylor and Francis, 1966. 120 p.

Messel H. and S.T. Butler. *Space Physics and Radio Astronomy.* New York, Macmillan, 1964

Michel, John. *The Flying Saucer Vision.* London, Sidgewick and Jackson, 1967
The author examines the origins of the flying saucer cult and suggests that contact with extra-terrestrial life may develop gradually.

Millman, P.M. *This Universe of Space.* Available from C.B.C. Publications, Box 500, Toronto.
This booklet by a noted Canadian astronomer contains information on all branches of astronomy.

Moore, Patrick. *The Amateur Astronomer.* London, Lutterworth Press, 1967. 332 p.
It describes basic facts and suggests lines of work for the amateur.

Moore, Patrick. *Naked-Eye Astronomy.* London, Lutterworth Press, 1966. 251 p.
A book to open up a month-by-month study of constellations and planets.

Moore, Patrick. *Practical Amateur Astronomy.* London, Lutterworth Press, 1963. 254 p.
A comprehensive book of instructions for turning a hobby into a branch of research.

Moore, Patrick. *The Sky at Night.* London, Eyre & Spottiswoode, Volume I, 1964. 224 p. and Volume II, 1968. 272 p.
Since 1957 the *Sky at Night* has been running as a BBC television program.

Moore, Patrick. *Space.* London, Lutterworth Press, 1968. 216 p.
A full story of exploration with three hundred illustrations.

Moore, Patrick. *Survey of the Moon.* London, Eyre & Spottiswood, 1963

Moore, Patrick. *Yearbook of Astronomy, 1969.* London, Sidgewick and Jackson, 200 p.
This annual publication which includes star charts and information for locating the planets has become a standard reference book.

Muirden, James. *Astronomy with Binoculars.* London, Faber and Faber, 1963. 146 p.
Few people with binoculars realize the potential of these instruments.

National Aerospace Education Council. *Aerospace Bibliography.* Fourth Edition. 64 p. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. Price 40 cents.
This lists books, reference materials, periodicals, and teaching aids.

Newton, H.W. *The Sun.* Harmondsworth, Penguin, 1958
Written for the non-scientist, this is one of the best books on the sun.

Opik, E.J. *Initiation à l'astronomie.* Paris, Petite Bibliothèque Payot, 1960. 186 p.

Ordway, F.I., III and Wakeford, R.C. *Conquering the Sun's Empire.* New York, Dutton, 1965. 96p.
The author gives a planet-by-planet survey of how man may visit, explore and colonize the solar system.

Ordway, F.I., III. *Life in Other Solar Systems.* New York, Dutoon, 1965. 96 p.
On a solid basis of facts and figures, the author leads the reader to imagine, to suppose, to reason and to wonder.

Page, Thornton. (Editor). *Stars and Galaxies.* Englewood Cliffs, Prentice-Hall, 1962. 163 p.
Seven speakers, each recognized by other astronomers as expert in his field, described active areas of research at an Oklahoma City symposium.

Paul, H.E. *Outer Space Photography.* New York, Amphoto, 1967

Paul, H.E. *Telescopes for Skygazing.* New York, Amphoto, 1965

Petrie, William. *Keoeeit: The Story of Aurora Borealis.* Oxford, Pergamon, 1963. 134 p.
A scholarly yet readily readable account of a beautiful natural phenomenon written by a Canadian scientist.

Rackham, T. *Moon in Focus.* Oxford, Pergamon, 1968. 190 p.
This book describing the moon surface is rich in data, and well illustrated.

Reichen, Charles Albert. *Histoire de l'astronomie.* Lausanne, Edition Recontre, 1963. 105 p.
A very attractive, beautifully-illustrated book.

Reiter, Elmar R. *Jet Streams.* New York, Doubleday, 1967. 189 p.
The fundamental principles are described graphically and with equations.

Rey, H.A. *The Stars, a New Way to See Them.* Boston, Houghton Mifflin, 1952. 160 p.
Used in many elementary schools for identification of constellations because of the simple sketches.

Romaldi. (Editor). *La grande aventure de l'espace.* Paris, Romaldi, 1967. 431 p. et 397 p.
This is an encyclopaedia devoted to all branches of spatial research: rockets, satellites, man in extra-terrestrial space, astronomy and astrophysics, the conquest of the moon, modern astronautics.

Rudaux, Lucien and G. Vaucouleurs. *Larousse Encyclopedia of Astronomy.* London, Paul Hamlyn, 1959. 506 p.
A guide to astronomy clearly written and well-illustrated.

Scientific American. *The New Astronomy.* New York, Simon and Schuster, 1955. 246 p.
Twenty reprints of articles by Gamow, Hoyle and others ranging from cosmology, and curvatures of space to modern instrumentation.

Scientific American. *The Universe.* New York, Simon and Schuster, 1957. 142 p.
Eleven reprints of articles written by experts describing the universe and its possible origin.

Shapley, Harlow. *Source Book in Astronomy. 1900 – 1950.* Cambridge, Harvard University Press, 1960

Smart, W.M. *The Riddle of the Universe.* London, Longmans, Green, 1968. 228 p.
This survey of the main facts and theories shows the universe as much a riddle today as it ever was.

Sullivan, Walter. *Assault on the Unknown.* New York, McGraw-Hill, 1961
The book describes events in the International Geophysical Year.

Taylor, Sir Gordon. *The Sky Beyond.* Harmondsworth, Penguin, 1966. 192 p.
Mainly about the development of transoceanic flying by an Australian pioneer.

Taylor, L.B. Jr. *Liftoff.* New York, Dutton, 1968. 319 p.
The comprehensive illustrated story of Cape Canaveral as a space port.

Thompson, G.V.E. and K.W. Gatland. (Editors). *Materials in Space Technology.* London, Iliffe Books, 1963. 275 p.
The fourteen chapters describe in technical fashion the specialized materials needed for astronautics.

Trinklein, F.E. and C.M. Huffer. *Modern Space Science.* New York, Holt, Rinehart and Winston, 1967. 550 p.
An extensive treatment of discoveries and principles.

Tsiolkovsky, C. *Beyond the Planet Earth.* Oxford, Pergamon, 1960

Tsiolkowski, C. *Le chemin des étoiles.* Moscow, Editions en langues étrangères. 500 p.
This book is the first complete collection of the proposals of the great Russian space pioneer.

Tsiolkovsky, K. *The Call of the Cosmos.* Moscow, Foreign Languages Publishing House. 480 p.
The scientist-author, who died in 1935, tells about space travel by rocket.

UNESCO. *L'information à l'ère spatiale: le rôle des satellites de communication.* UNESCO, 1968. 219 p.

Velikovsky, I. *Worlds in Collision.* New York, Doubleday, 1950

Wood, Elizabeth A. *Science for the Airplane Passenger.* Boston, Houghton-Mifflin, 1968

Zhdanov G. and I. Tindo. *Space Laboratories.* Moscow, Foreign Languages Publishing House, 1962. 195 p.
This layman's book describes the dividends from satellite and rocket activities.

Other Learning Materials

McLaughlin Planetarium. Star charts, pictures, photographs, books, impactites and tektites may be purchased from the Bookstore Manager, McLaughlin Planetarium, 100 Queen's Park Crescent, Toronto 181. Advice regarding telescopes can be requested from Mr. Terence Dickenson, Curatorial Assistant of the Planetarium. It should be noted that the reference library is open for reading and research.

SFRB. *Space and Upper Atmosphere Research in Canada.* This publication (No. SRFB .024) that refers to research with balloons, rockets and satellites may be secured from the Space Research Facilities Branch, National Research Council of Canada, Montreal Road, Ottawa.

Institute for Aerospace Studies. This research centre publishes a *Bulletin,* and an *Annual Report* describing recent activities in university research. Each is available from the Director, Institute for Aerospace Studies, University of Toronto, Toronto 181.

Communications Research Centre. This centre has prepared for current use a *Press Kit on Isis-A* in the course of its work of satellite design. Requests for information may be made to the Director-General, Communications Research Centre, Department of Communications, P.O. Box 490, Ottawa 2.

CNES. Several publications can be secured free when requested from: La Division Information et Documentation de CNES (Centre Nationale d'Etudes Spatiales), 129 rue de l'Université, Paris (7e), France.

NASA. Information about publications can be obtained from the Educational Programs and Service Office, National Aeronautics and Space Administration, Washington D.C. 30546.

RASC. This organization is ready to answer questions regarding astronomy that are mailed to: The Secretary, Royal Astronomical Society of Canada, 252 College Street, Toronto, Ontario.

Photographs. The following suppliers carry a stock of photographic prints and slides in the field of astronomy.

- California Institute of Technology Bookstore, 1201 East California Boulevard, Pasadena, California, U.S.A.
- McLaughlin Planetarium, Royal Ontario Museum, 100 Queen's Park Crescent, Toronto 181, Ontario.
- Tersch Enterprises, P.O. Box 1059, Colorado Springs, Colorado, U.S.A. 80901.

Lovell, Sir Bernard. *Our Present Knowledge of the Universe.* This 12" LP (33 1/3 rpm) record can be purchased from CBC Publications, Box 500, Toronto, Terminal A. This address which was delivered to a non-specialist audience deals with man's quest to determine the origin of the universe and our own system.

Flammes du Soleil. This film honouring the work of astronomer Bernard Lyot includes Lyot's original cinematographic and photographic records of solar flares made at the Observatory at Pic du Midi. Produced by La Cinégraphie Documentaire in France in 1952, this black and white film runs for 20 minutes. The film, available only with commentary in French may be borrowed from the Learning Materials Service Unit, 559 Jarvis Street, Toronto 285.

Ronin, Colin. *The Discovery of the Galaxies: Science Jackdaw Two.* London, Jonathan Cape, 1967. This assortment of broadsheets, letters, photographs, drawings and charts provides a random source from which students can develop their own conceptual schemes.

Learning Materials Service Unit. The Department of Education provides a film loan service from this address: Learning Materials Service Unit, 559 Jarvis Street, Toronto 285. A partial .ist of films related to *Space and Man* follows.

SG.148 Space Science : The Planets
SG.92 Exploring the Edge of Space
SP.22 Theory of Flight
SG.106 Satellites: Stepping Stones to Space
SG.88 Earth Satellites
SG.105 Rockets : How They Work
SG.149 Why Communication Satellites